

Activity 4

Effects of Plate Tectonics



Goals

In this activity you will:

- Use maps to examine the distribution of earthquakes and volcanoes to the location of plate boundaries.
- Explain the location, nature, and cause of volcanic arcs in terms of plate tectonics.
- Explain the location, nature, and cause of hot spots.
- Explain how plate-tectonic processes have caused continents to grow through geologic time.
- Explain how plate-tectonic processes produce landforms.
- Explain how plate tectonics can affect the interior of a continent.

Think about It

Rocks high in the Himalayas, almost 8000 m (29,028 ft) above sea level, contain fossils of marine animals.

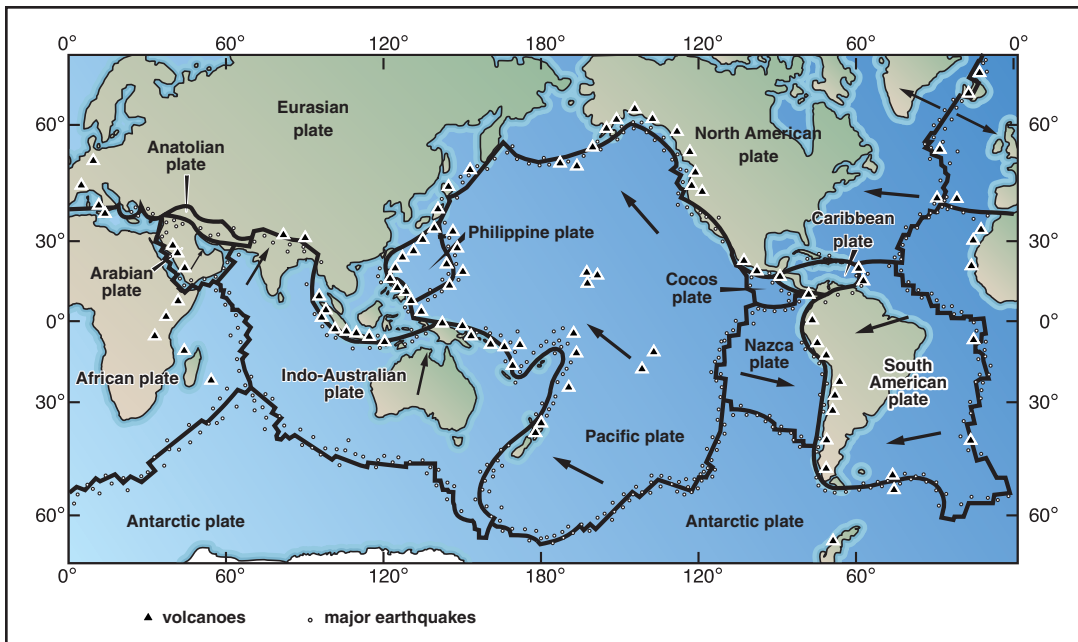
- Why are most high mountain ranges located at or near plate boundaries?

What do you think? Record your ideas about this question in your *EarthComm* notebook. Include sketches as necessary. Be prepared to discuss your response with your small group and the class.



Investigate

- Compare the distribution of volcanoes and earthquakes shown on the following map with the map of crustal plates you created in **Activity 2**.
 - Describe any differences between the distribution of volcanoes along plate boundaries and within plate interiors.
 - Describe any differences between the distribution of earthquakes along plate boundaries and within plate interiors.
- To model the rise of magma through the Earth, fill a tall, transparent jar almost up to the brim with honey. Put a very small volume of vegetable oil (about 5 mL, one teaspoon) on top of the honey. Screw on the lid. Try not to leave any air in the container. Turn the container upside down quickly and set it on a tabletop. Make your observations and answer the following questions:
 - What does the honey represent?
 - What does the vegetable oil represent?
 - Describe and explain the behavior of the vegetable oil.
 - What do you think are the similarities and differences between the behavior of this model and the rise of magma in the Earth?



World map showing the location of volcanoes and large earthquakes.

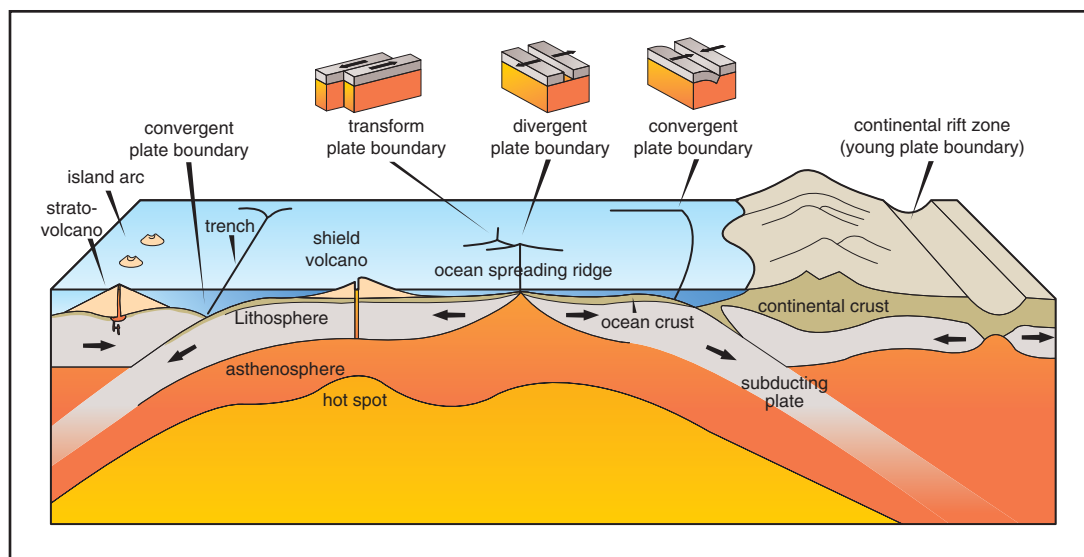


Be sure the lid is on tight
before the jar is turned over.
Clean up spills immediately.

3. The diagram shows a cross section with two subduction zones, a spreading ridge, and a continental rift. Note the two zones where an oceanic plate is being subducted (plunged) under another plate. Volcanoes are common in a zone that is located a certain distance away from the trench where the subducted plate first bends downward.

In your group, develop as many hypotheses as you can think of for why the volcanoes occur, and why they are located where they are. Here are four important facts you might need to use or think about in developing your hypotheses:

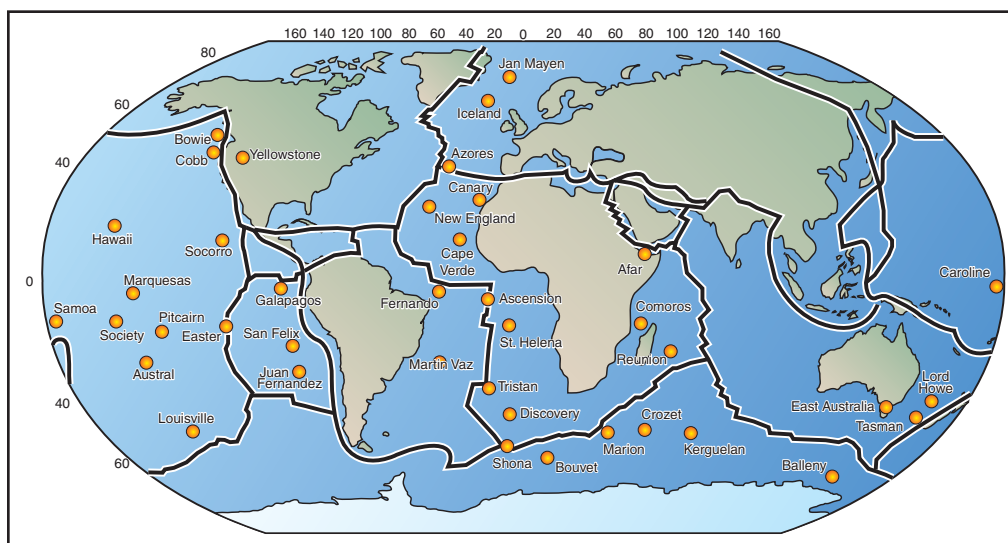
- (i) The downgoing plate is cooler than the mantle.
 - (ii) The composition of the downgoing plate is slightly different from the composition of the mantle. (Why?)
 - (iii) The oceanic crust on the downgoing plate contains water, which was added to the igneous rocks when they formed.
 - (iv) Friction generates heat.
- a) Record your group's hypothesis.
 - b) In a class discussion, compare the hypotheses you developed in your group with those of other groups. Were their hypotheses different from yours and still seemed reasonable?



Cross-section with two subduction zones.



4. Look again at the diagram of the cross section with two subduction zones. Use the cross section to answer the following questions:
 - a) Under what two types of plates is the oceanic lithosphere being subducted?
 - b) What differences between oceanic volcanic arcs and continental volcanic island arcs can you see or infer from the cross section?
 - c) On a copy of the map of volcanoes and earthquakes, circle two continental volcanic arcs and three oceanic volcanic arcs.
 - d) In which part of the world are most volcanic arcs located? What does that suggest about the plate-tectonic setting of that part of the world?
5. To understand why volcanic arcs are called arcs, look at the Andes Mountains on a topographic map. The Andes are topped with volcanoes that are part of a volcanic arc. They appear to run along a straight line. Run a string or thread along their length on a globe.
 - a) What is the shape of the line on the globe? Why are lines of volcanoes called arcs?
 - b) Using the cross section of the subduction zones, explain why few volcanoes occur very far inland within a continent.
 - c) If volcanic rock is found far inland within a continent, what is one possible reason why it is there?
6. One reason why volcanic rock might be located in the interior of a plate is illustrated on the cross section of the subduction zones where a hot spot is shown in the middle of one of the oceanic plates.
 - a) Where does it appear that the hot spot originated?
 - b) Is it related to subduction?
 - c) Where does the hot spot begin to produce a pool of magma?
7. The map on the next page shows hot spots around the world:
 - a) Where are most hot spots?
 - b) Are they clustered or randomly located?
 - c) What famous area of the continental United States sits over a hot spot?
 - d) What sits atop another famous hot spot in the United States?



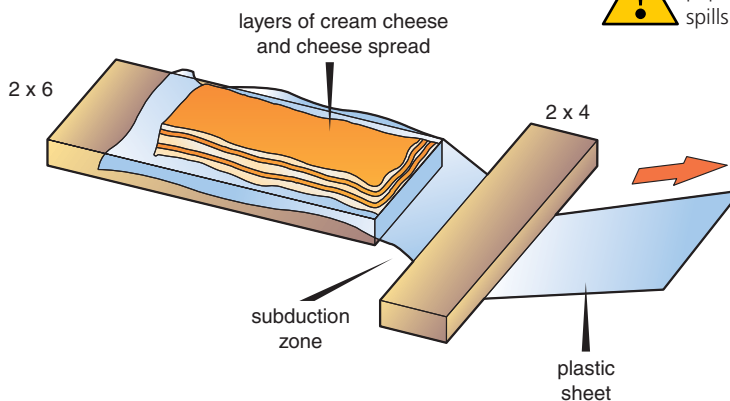
Map of hot spots around the world.

8. To model the growth in size at a subduction zone, set up pieces of lumber and a plastic sheet as shown in the diagram. With a table knife, spread a thin (about 2 mm) layer of cream cheese on the part of the plastic sheet that rests on the upper surface of the 2 x 6. Try to keep the layer as even in thickness as you can. Spread a layer of the cheese spread, of about the same thickness, over the layer of cream cheese.

Have one student hold the piece of 2 x 4 in place, pressing down on it

gently. Another student very slowly pulls the loose end of the sheet of plastic out from under the 2 x 4. Observe what happens to the layer of cream cheese and cheese spread as “subduction” proceeds.

- a) In your notebook, write a description of the process you observe. Be sure to note how the body of material at the subduction zone changes its shape, as well as its volume through time.



Keep work area clean. Have damp paper towels ready to wipe up spills and clean hands as required.



9. After all of the sheet of plastic has been consumed down the subduction zone, make a cut through the accumulated cream cheese and cheese spread, to see the internal structure of the new material at the subduction zone. The cut should be vertical, and parallel to the direction of subduction. Clear away all the material from one side of the cut and examine the face of the cut.
 - a) In your notebook, draw a sketch of what the cut looks like. Show the topographic profile of the top of the material, and also any internal structures you observe.
 - b) Is there a limit to the height of the “mountain range” that is formed at the subduction zone?
 - c) Did any of the cream cheese and cheese spread go down the subduction zone (under the 2 x 4)? In a real subduction zone, what would happen to such material? (This is not a perfect model of what happens to oceanic sediment at a subduction zone, but it gives you the flavor of it. Geoscientists love to make puns.)

Reflecting on the Activity and the Challenge

In this activity you have observed features on the Earth's surface that are created as a result of crustal plate movements and activity within the geosphere. You have also seen that plate-tectonic processes can cause plates to grow in size. Finally, you

have seen that plate movements can cause earthquakes that can be associated with specific plate boundaries. You will need to consider these surface features and disturbances created by plate motions in order to complete your **Chapter Challenge**.

Geo Words

plate tectonics: the field of study of plate motion.

Digging Deeper

“BUILDING” FEATURES ON EARTH'S SURFACE

Plate Tectonics

You can now see why the field of study of plate motion is called **plate tectonics**. Tectonics comes from the Greek word *tekton*, which means builder. Plate tectonics refers to the building of the features on Earth's surface due to deformation caused by plate movements.

You have learned that plate movements create mountain ranges, trenches, and rift valleys at or near plate boundaries. Also, there is a clear relationship between volcanoes and plate boundaries, and between earthquakes and plate boundaries. This is particularly evident around the rim of the Pacific Ocean,

where the subduction of oceanic plates around much of the rim results in volcanic arcs and earthquakes.

Oceanic Trenches

The deepest valleys on Earth are in the ocean, where they can't be seen except from special deep-diving submersibles. Where an oceanic plate is subducted under another plate, it bends downward as it enters the subduction zone. The valley that is formed above the zone of bending is called a trench. Oceanic trenches are very deep. Many are deeper than 10,000 m, which is twice the average depth of the deep ocean. The word "valley" is a bit misleading, because trenches are wide, and their side slopes are not very steep. You can easily spot the locations of trenches in most world atlases, because they are shown with the darkest blue shading on maps of the world's oceans. Trenches are common in many places in the western Pacific, where there is ocean-ocean subduction. There is a long trench along the west coast of South America, where the Nazca Plate is being subducted under the continent.

Volcanoes at Plate Boundaries

You know already that volcanoes are common along mid-ocean ridges, where basalt magma rises up from the asthenosphere to form new oceanic crust. Volcanoes are also common along subduction zones, where they form volcanic arcs. At a depth of 200 to 300 kilometers, magma is produced above the subducted plate, and rises toward the surface because it is less dense than the surrounding rock. At first it was thought that the magma was produced as rock near the top of the downgoing plate and was heated by friction, but geoscientists are now convinced that the melting is for a different reason. When the oceanic crust is first produced, at the mid-ocean ridges, a lot of water is combined with certain minerals in the igneous rocks. As the pressure and temperature increase down the subduction zone, this water is driven off, and it rises upward from the plate. It's known that the melting temperature of the mantle rock above the plate is lowered when water is added to it. This causes some of the mantle rock to melt. This is a good way to explain why melting doesn't start until the plate has reached a certain depth down the subduction zone, and then stops at a slightly deeper depth. The "Ring of Fire" around the Pacific Ocean is caused by this melting at subduction zones all around the Pacific.

Hot Spots

Not all volcanoes are associated with mid-ocean ridges and subduction zones. Hot spots, which originate at the boundary between the mantle





and the outer core, are narrow plumes of unusually hot mantle material. These plumes rise up through the mantle and melt the rock at the base of the lithosphere, creating pools of magma. This magma then rises to the surface, resulting in hot spot volcanoes.

Some hot spots are located under continents. The hot spot producing the hot springs at Yellowstone National Park is an example. One theory suggests that the bulge created by a hot spot may initiate the rifting of a continent. It is thought that a hot spot lies below, and is responsible for, the Rift Valley of Africa. There is also evidence suggesting that the New Madrid fault, which runs down the Mississippi River Valley, may represent an aborted rift zone originally created by a series of hot spots. The largest series of earthquakes in the United States, outside of Alaska, occurred on the New Madrid fault in the early 19th century, ringing bells as far away as Philadelphia and causing the Mississippi River to run backwards for a short time! In this way, plate tectonics can even affect areas that are within the heart of a continent.



Mountains at Plate Boundaries

Most of the great mountain ranges of the world are located near convergent plate boundaries. When someone says “mountain ranges” to you, which of them do you think of? The Alps in Europe, the Himalayas in southern Asia, the Andes in South America, and the coastal mountain ranges in western North America are some examples. Mountain ranges like those are built in mainly two ways. You already know that the magma that is generated above the subducted plate rises up to form a chain of volcanoes. Much of

the magma remains below the surface and cools to form large underground masses of igneous rock called batholiths. The combination of volcanoes at the surface and batholiths deep in the Earth adds a lot of new rock to the area above the subduction zone, and makes the elevation of the land much higher. Also, many subduction zones experience compression, when the two plates are pushed together by plate movements elsewhere. In places like that, great masses of rock are pushed together and stacked on top of one another in complicated structures, to form high mountains. This happens also where two continents collide with each other, as in the Himalayas.

Growth of Continents at Subduction Zones.

During the long travels of an oceanic plate from a mid-ocean ridge to a subduction zone, a hundred meters or more of oceanic sediment is deposited on the top of the plate. In Part 6 of the investigation, you saw how a lot of this sediment is scraped off and added to the edge of the other plate. This material, which is deformed into very complicated structures, is turned into rock by heat and pressure. It becomes a solid part of the other plate. When material is added to the edge of a continent in this way, the continent grows larger at its edge. Continents also grow as the igneous rock of volcanoes and batholiths are added to the continent above the subduction zone, as described above. The growth of a continent along its edge in these ways is called **continental accretion**. This has been going on through geologic time, making the continents larger and larger.

Earthquakes and Plate Tectonics

As plates move past each other at plate boundaries, they don't always slide smoothly. In many places the rocks hold together for a long time and then slip suddenly. You will learn more in Chapter 3 about how earthquakes are caused in this way. Earthquakes along mid-ocean ridges are common because of movement along the transform faults that connect segments of the ridge crest. Only where transform faults are on land or close to land, as in California, are these earthquakes likely to be hazardous. As you saw in Activity 2, the famous San Andreas fault in California is a transform fault. Earthquakes at subduction zones and continent–continent collision zones are a bigger problem for human society, because these areas are so common on the Earth, especially around the rim of the Pacific and along a belt that stretches from the Mediterranean to southeast Asia. Earthquakes in subduction zones happen at depths that range from very shallow, near the trench, to as deep as hundreds of kilometers, along the subducted plate. Earthquakes in continent–continent collision zones happen over wide areas as one continent is pushed under the other.

Geo Words

continental accretion: the growth of a continent along its edges.

Check Your Understanding

1. Why is plate tectonics a suitable name for the study of plate motion. Explain.
2. What geographic features would you expect to see at plate boundaries.
3. How do geoscientists suggest that “hot spots” are related to plate tectonics.
4. In your own words explain the process of continental accretion.



Understanding and Applying What You Have Learned

1. Review your work with earthquakes and volcanoes one more time.
 - a) Summarize where most earthquakes are located compared to plate boundaries.
 - b) Summarize where most volcanoes are located compared to plate boundaries.
2. Although most earthquakes and volcanoes are associated with plate boundaries, they are not always located directly along the boundaries. Considering boundaries between oceanic and continental plates:
 - a) Why are volcanoes usually found on the continental side of a plate boundary?
 - b) Why are earthquakes usually found on the continental side of a plate boundary?
3. Many volcanoes and earthquakes are found far from modern plate boundaries. Write a paragraph giving one idea you think might explain how at least some of them have formed. Be sure to point out examples by describing their location.
4. Make a list of the various plate-tectonic settings where mountain ranges are likely to be produced. For each item on the list, draw a cross section that shows the mountain range and how it relates to the plate-tectonic setting. For each item, give an example from somewhere in the world.

Preparing for the Chapter Challenge

In this activity you have learned that plate tectonics has an influence on every part of the world. Surface features and movements caused by plate tectonics are not only at plate boundaries, but also at locations far from modern plate boundaries. Write

a paragraph, based on what you now know of movements or features in your region that indicate plate-tectonic activity (whether it is nearby or far away). Carefully list your evidence so you can present it to the middle school class.

Inquiring Further

1. Plate tectonics and the local climate

Distant mountain ranges and plateaus created by plate tectonics can affect air flow in many ways, affecting local climate and thus vegetation, soil,

wildlife, and drainage patterns. Research and report on how your local region has been affected directly or indirectly by plate tectonics. You may even wish to include some of this research in your **ChapterChallenge**.